DEPARTMENT OF FOOD, AGRICUTURAL AND BIOLOGICAL ENGINEERING

Techno-economic analysis of levoglucosan production via fast pyrolysis of cotton straw in China

Junqi Wang[1], Ajay Shah[1]*

INTRODUCTION

- China, one of the largest agricultural countries in the world, is rich in agricultural biomass resources. The yield of cotton straw is projected to increase by 7.2% annually[1]. Cotton straw is usually combusted directly in the countryside, which largely pollutes the environment.
- Cotton straw is a suitable resource for the production of bio-oil via fast pyrolysis, which can be further upgraded to a high value product, levoglucosan, through extraction[2].
- Levoglucosan can be used for several applications, such as, pesticides, growth regulators, macrolide antibiotics[3].
- Levoglucosan can be obtained via fast pyrolysis and extraction, but its techno-economic feasibility is unknown.

AIM

Investigate the techno-economic feasibility of the production of levoglucosan through fast pyrolysis of cotton straw in China.

METHODS

Software: SuperPro Designer v 9.5

System boundary: Depicted in Figure 1

Annual processing capacity: 200,000 ton of cotton straw

Data collection:

- Bio-oil and levoglucosan yield data
- Process parameters: such as temperature, pressure and time
- Facilities and equipment data
- Prices for different systems and consumables

Data sources: Collected from lab experiments, literature[1] and personal communication with experts

Analysis:

- Material balance and energy requirements
- Capital investment
- Operating cost
- Sensitivity analysis

Financial analysis: Gross margin (GM), return on investment (ROI), internal rate of return (IRR), net present value (NPV) and payback time (PBT) for different levoglucosan price conditions (see Table 1 for details).

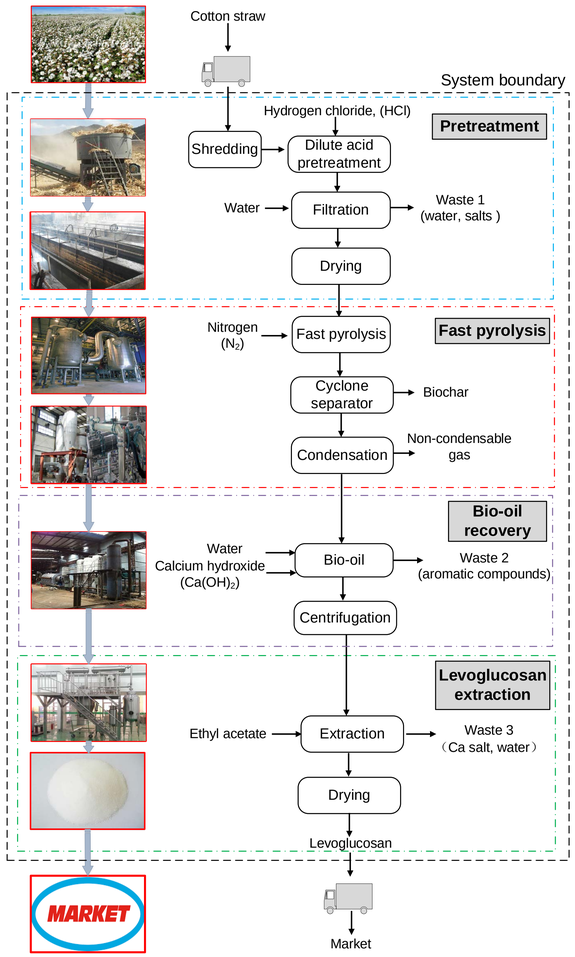

Figure 1. Process diagram and system boundary

RESULTS

Material balance and energy requirements

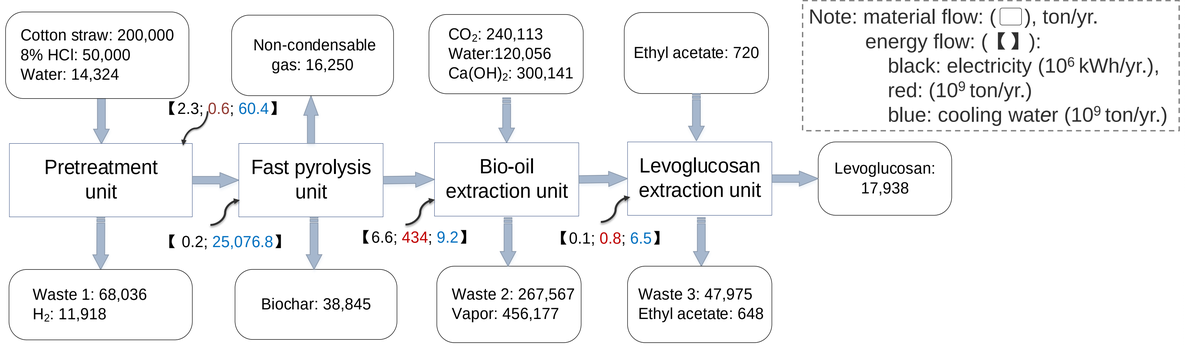

Figure 2. Mass balance and energy requirement

- The estimated levoglucosan production was almost 18,000 ton, with a yield of around 9% (dry weight) of cotton straw.
- The annual total external energy requirements: 11.4 ×10^6 kWh for electricity consumption; 435.4 ×10^9 ton for steam consumption ; 25,152.9 ×10^9 ton for cooling water consumption.

Capital investment

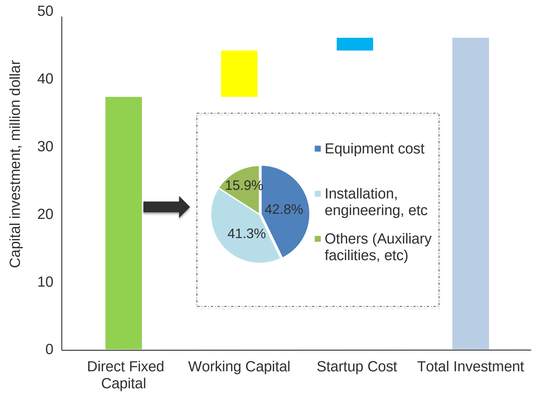

Figure 3. Capital investment

- Total capital investment for levoglucosan production was estimated to be around $46 million.
- The direct fixed capital cost (equipment cost, installation, engineering cost) was about 81% of the total capital investment.
- The purchasing price of processing equipment accounted for around 43% of the direct fixed capital cost and with around 41% of the direct fixed capital cost required for installation, buildings materials, engineering, and construction.

Operating cost

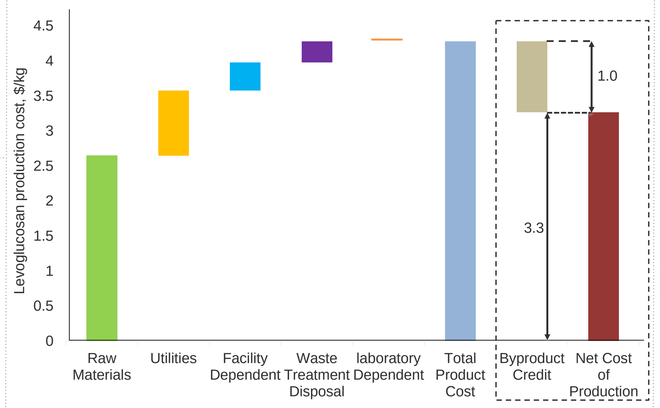

Figure 4. Levoglucosan production cost

- Annual operating cost for levoglucosan production was estimated to be $77.1 million. The gross cost of levoglucosan was about $4.3/kg.
- Raw materials cost was the major contributor to the annual operating cost. It included the costs of cotton straw and the other input materials ($Ca(OH)_2$, HCl).
- This plant generated about $17.9 million annual credits from byproducts, mainly biochar and non-condensable gases.
- Considering byproduct credits, the net levoglucosan cost was estimated to be $3.3/kg.

Sensitivity analysis

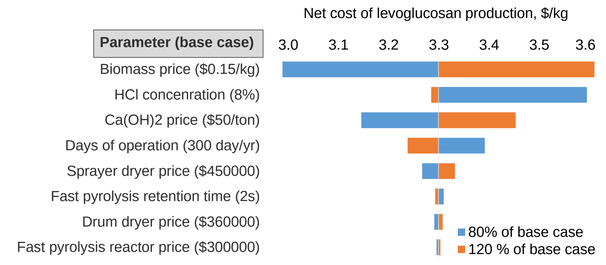

***Figure 5**. Sensitivity analysis*

The sensitivity analysis showed that cotton straw price, $Ca(OH)_2$ price, HCl concentration, and days of operation were the key parameters influencing the price of levoglucosan production.

Financial analysis

***Table 1**. Financial analysis*

Price conditions	Levoglucosan price ($/kg)	GM (%)	ROI (%)	IRR (%)	NPV (million $)	PBT (year)
Factory in Henan, China	3.5	5.1	14.0	13.1	14.8	7.1
Factory in Shaanxi, China	4.5	22.4	42.9	46.8	125.9	2.3
120% of production cost	3.9	12.9	25.6	28.4	59.5	3.9
150% of production cost	4.9	27.6	54.5	57.3	170.3	1.8
Lowest price in Alibaba	10.0	61.2	201.9	145.6	735.3	0.5
Average price in Alibaba	25.0	83.6	635.5	278.5	2,396.9	0.2
***Minimum selling price**	3.6	7.2	16.9	17.3	26.2	5.9

- Changing the market price ($/kg) from 3.5 to 4.9 increased the IRR from 17.3% to 57.3%.
- *For a project, involving a rather high-risk level, the suggested IRR is usually 15%[4], so, to achieve a 15% IRR, the minimum levoglucosan selling price was $3.6/kg for this system.
- The established minimum levoglucosan selling price was much lower than the commercial price[5].

CONCLUSIONS AND FUTURE WORKS

- The levoglucosan production via fast pyrolysis and extraction of cotton straw has a high potential to be an attractive alternative source of biochemicals.
- Future work should focuse on the utilization of levoglucosan and the life cycle assessment of levoglucosan production and utilization.

BIBLIOGRAPHY

1. Wang J *et al*. J. Anal. Appl. Pyrol. 2016
2. Helle S. *et a*l. Carbohydr. Res. 2007
3. Zhang Y. *et al*. Bioresour. Technol. 2013.
4. Ozerdem B. *et al*. J. Wind Eng. Ind. Aerod. 2006
5. Alibaba. https://www.alibaba.com/

ACKNOWLEDGEMENTS

China Scholarship council, OSU/OARDC/FABE, USDA-NIFA Hatch Project: 1005665

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

[1]DEPARTMENT OF FOOD, AGRICUTURAL AND BIOLOGICAL ENGINEERING, THE OHIO STATE UNIVERSITY, OHIO, USA
*Email: shah.971@osu.edu